

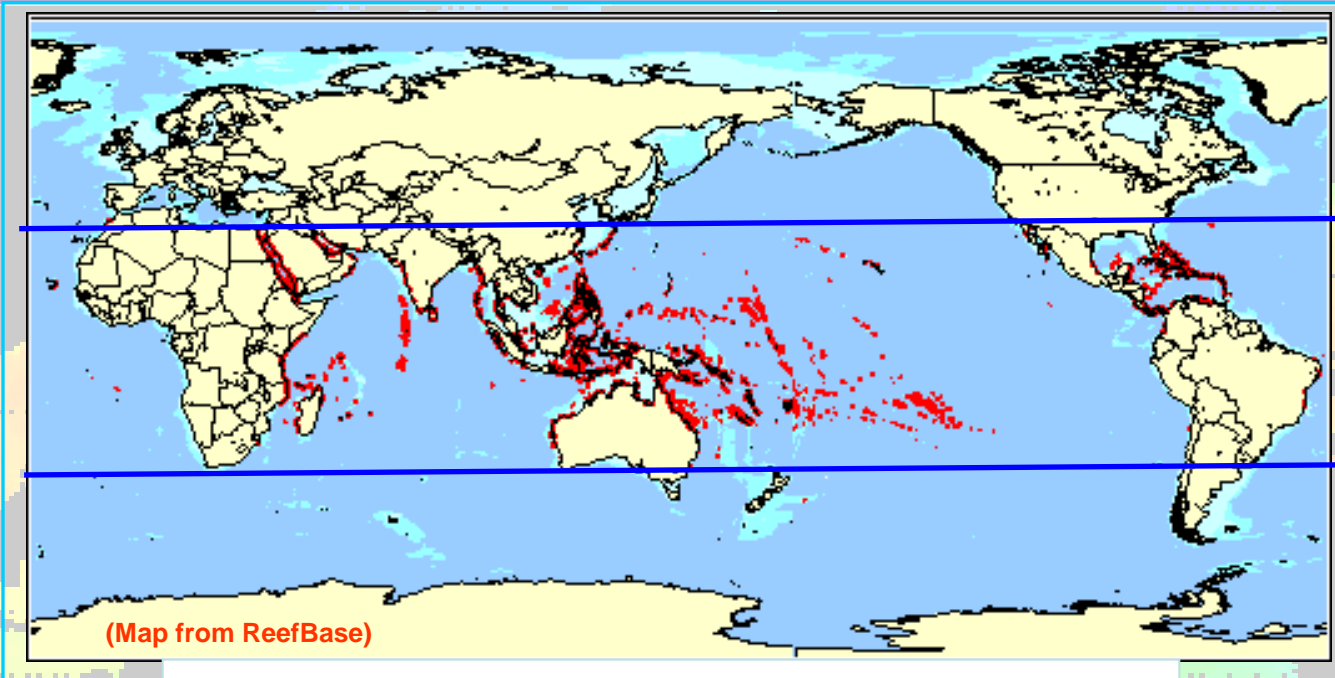
# NOAA Coral Reef Watch: Monitoring Coral Bleaching Potential Using NOAA 5 km Geo-Polar Blended SST

**Gang Liu, Scott F. Heron, C. Mark Eakin, Jacqueline L. De La Cour  
Erick F. Geiger, Kyle Tirak, William J. Skirving, Timothy F. R.  
Burgess, Alan E. Strong, Andy Harris, Jonathan Mittaz,  
Eileen Maturi, Alexander Ignatov, John Sapper**

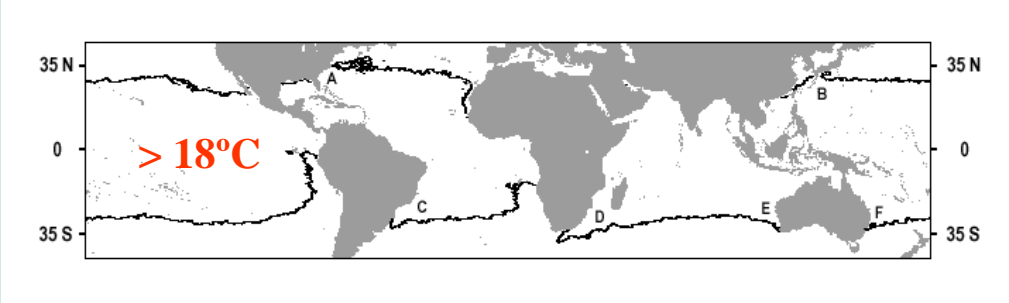


<http://coralreefwatch.noaa.gov>

# Distribution of World's Coral Reefs

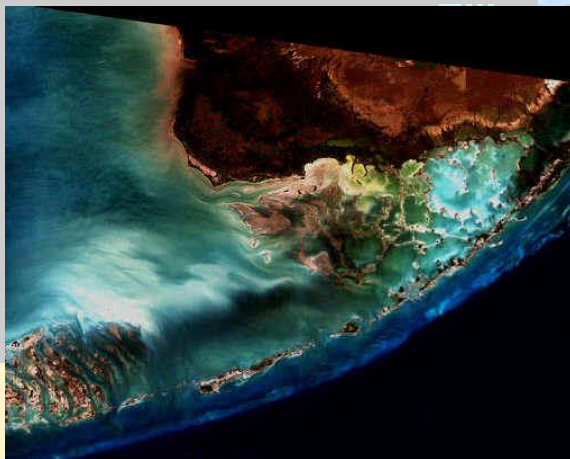


(35S-35N)



- Coral reefs thrive in global tropical regions: >18° C (35S-35N)
- Covering less than 1% of the Earth's surface
- Providing habitat for 25% of all known marine species

# Coral Reef Areas as Seen from Space & Air



Florida Keys



Great Barrier Reef, Australia



Maldives-atolls



Rose Atoll, American Samoa



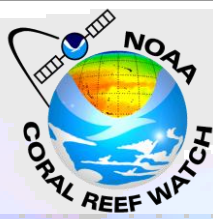
Johnston Atoll



Midway Atoll

Spatial scale of individual reefs: meters to tens of kilometers

# Coral Reefs

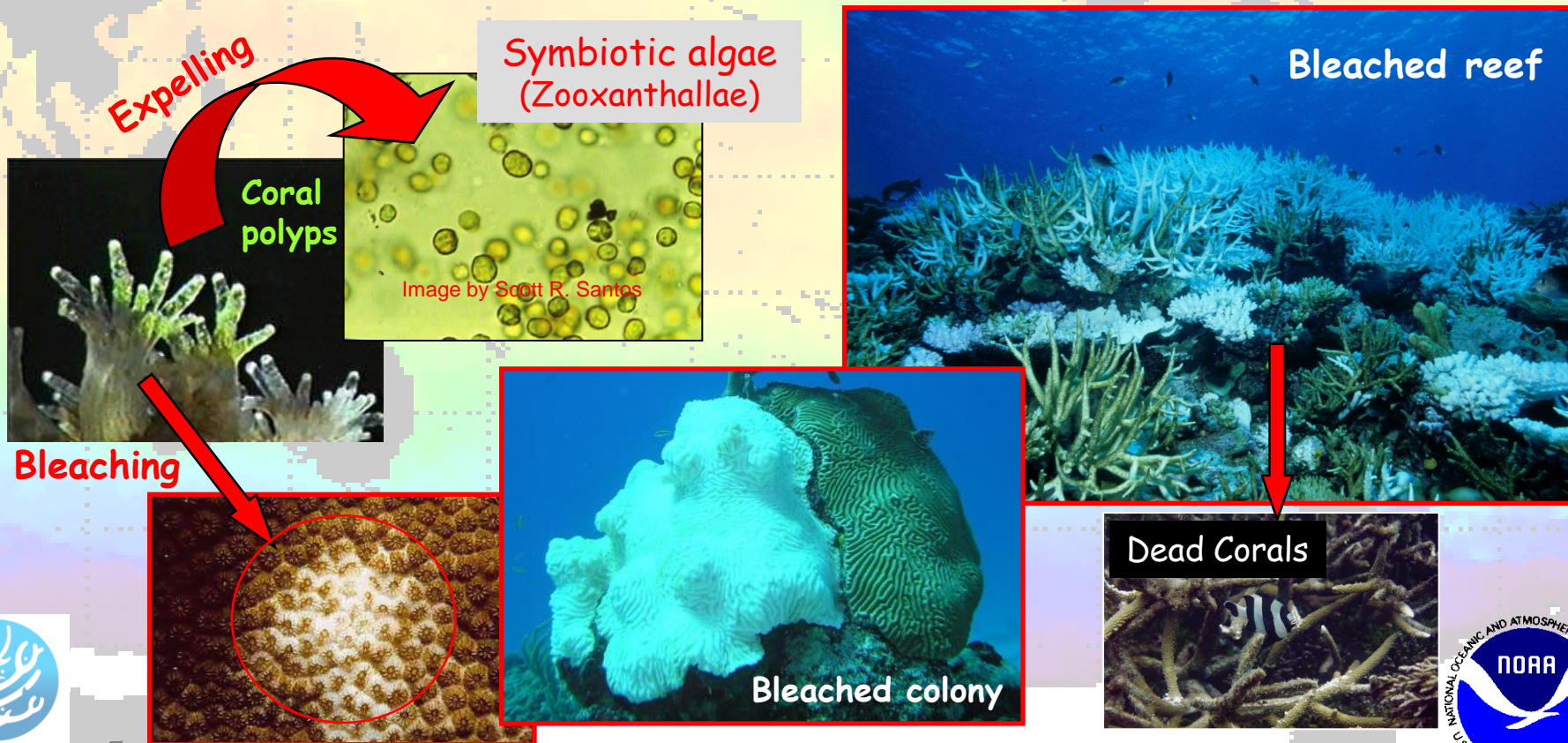


Spatial scale of individual reefs: meters to tens of kilometers

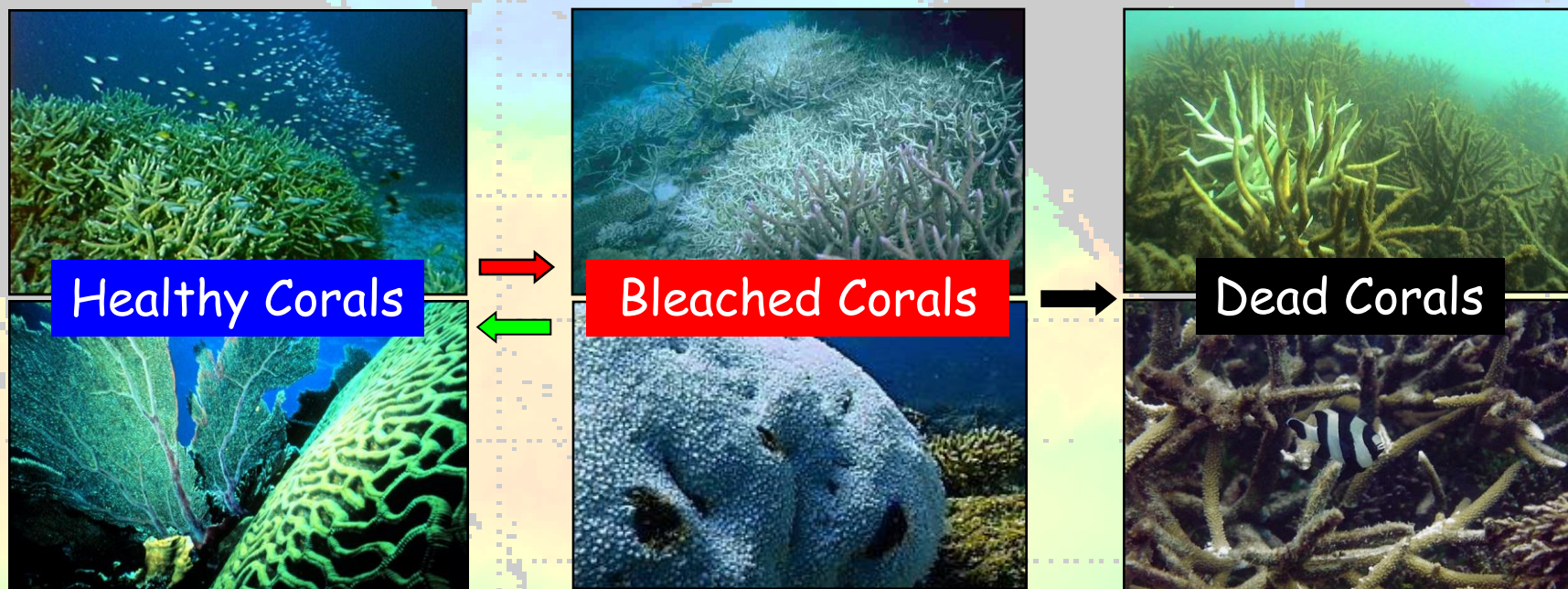


# Coral and Coral Bleaching

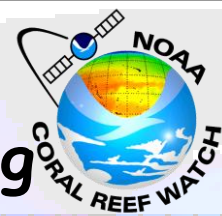
- Symbiotic relationship between corals and algae may break down under certain environmental stresses: host corals expel algae;
- Bleached colony becomes pale, even stark white, revealing its underlying white calcium carbonate skeleton through translucent coral tissue;
- Severe or long-lasting stress leads to coral death;
- Bleached corals are susceptible to disease outbreak.



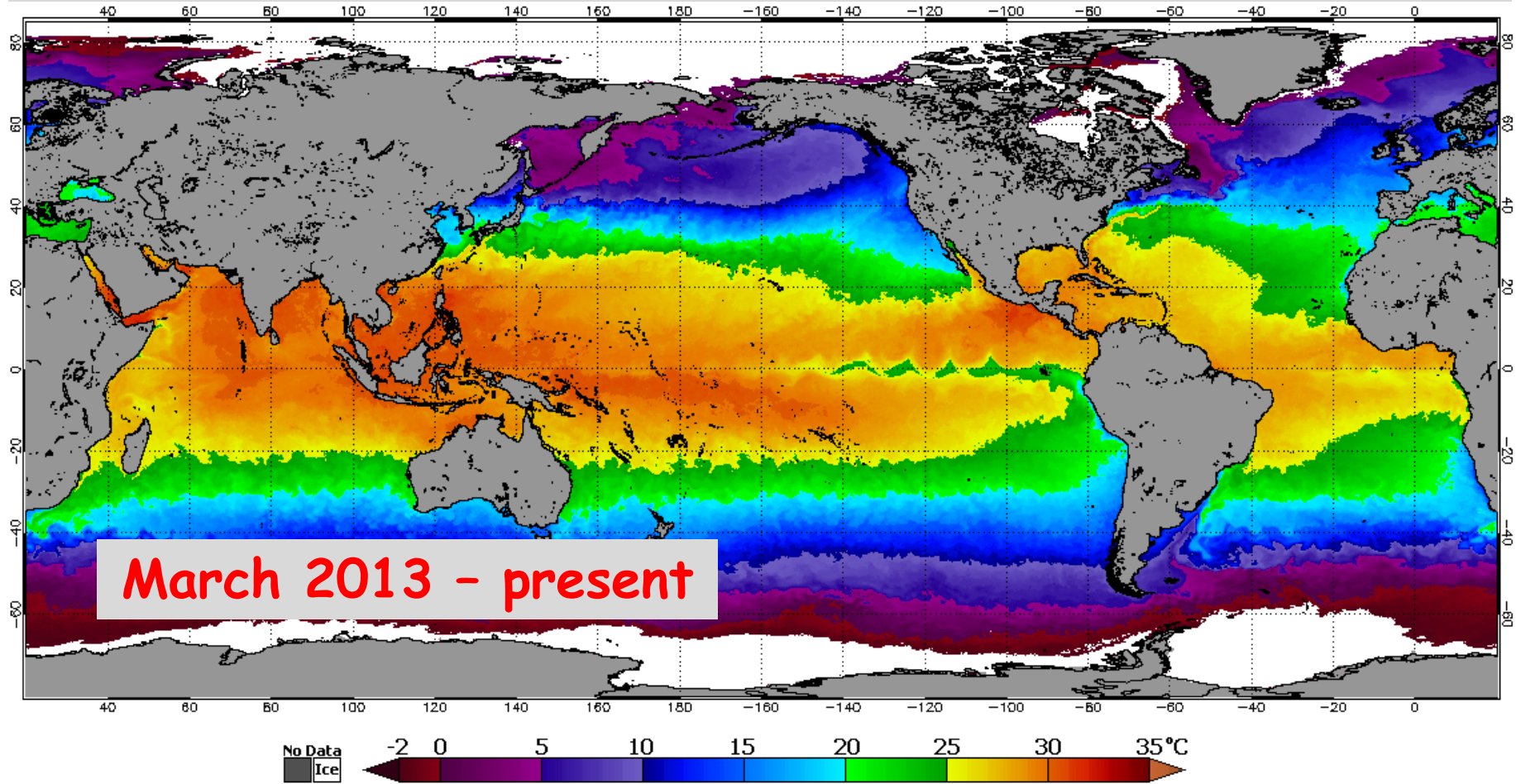
# Coral Bleaching & Coral Reefs in Crisis



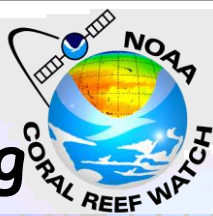
- Dramatic long-term ecological and social consequences
- High-temperature induced bleaching has increased in frequency & intensity over the past few decades
- A major threat to the world's coral reefs



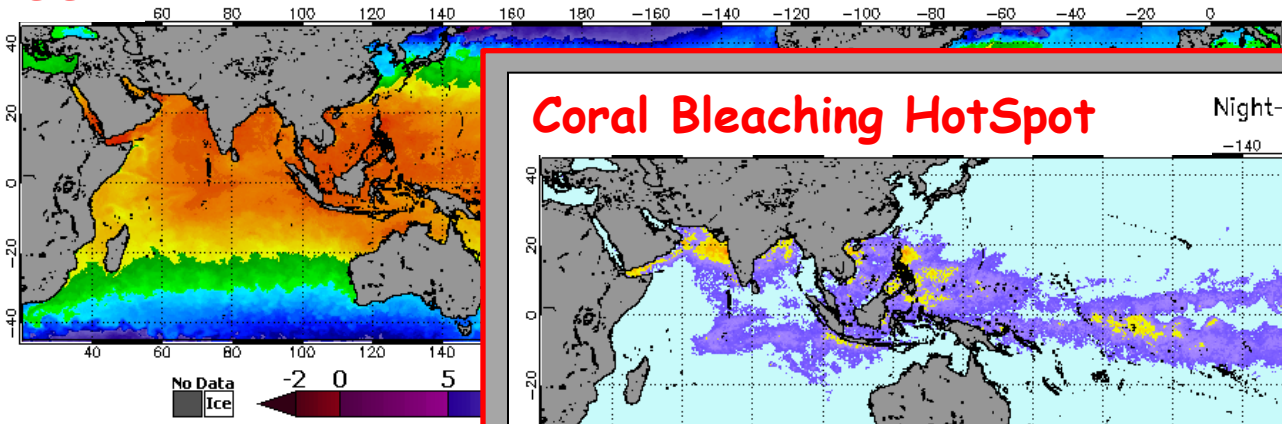
## NOAA/NESDIS Operational Daily Global 5 km Geo-Polar Blended Night-only SST Analysis



# Next-generation Bleaching Thermal Stress Monitoring

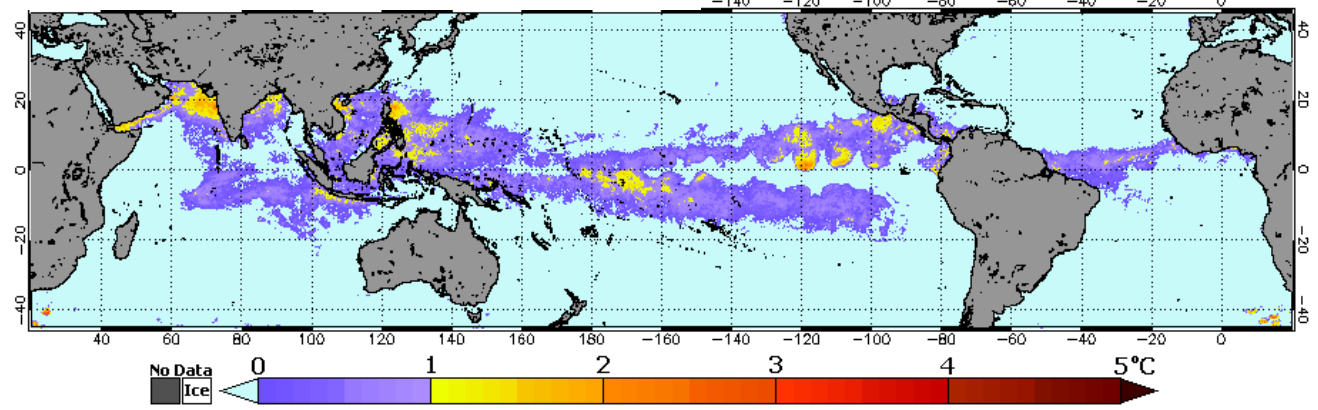


**SST** Reef Watch Daily 5-km Geo-Polar Blended Night-Only Sea Surface Temperatures 3 Jun 2016



**Coral Bleaching HotSpot**

Night-Only HotSpots 3 Jun 2016



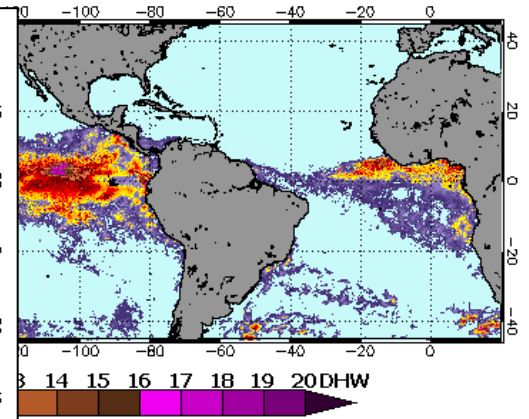
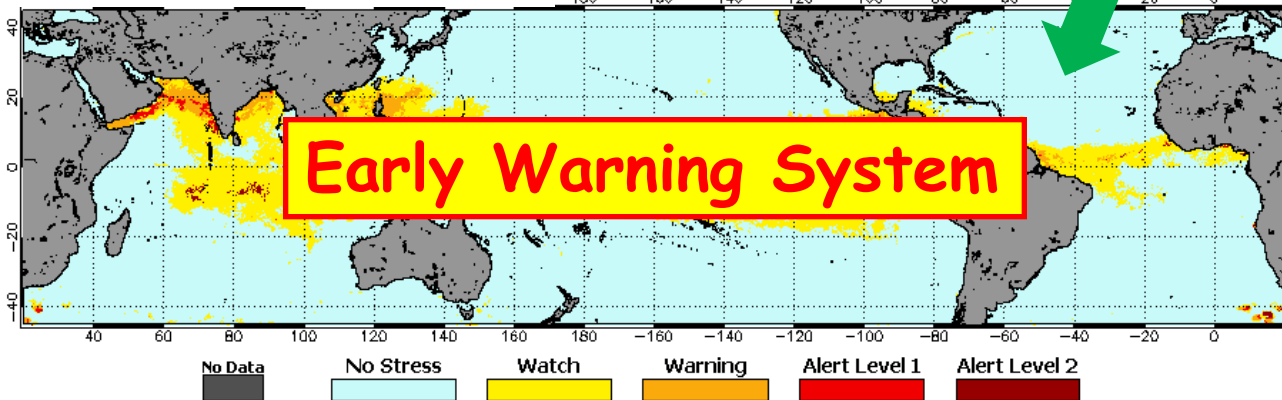
- Global 5 km
- Updated daily

**Degree Heating Week**

Blended Night-Only Degree Heating Weeks 3 Jun 2016

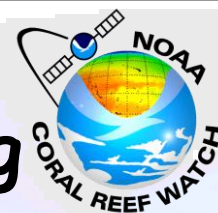
**Bleaching Alert Area**

Blended Night-Only Bleaching Alert Area 7d 3 Jun 2016



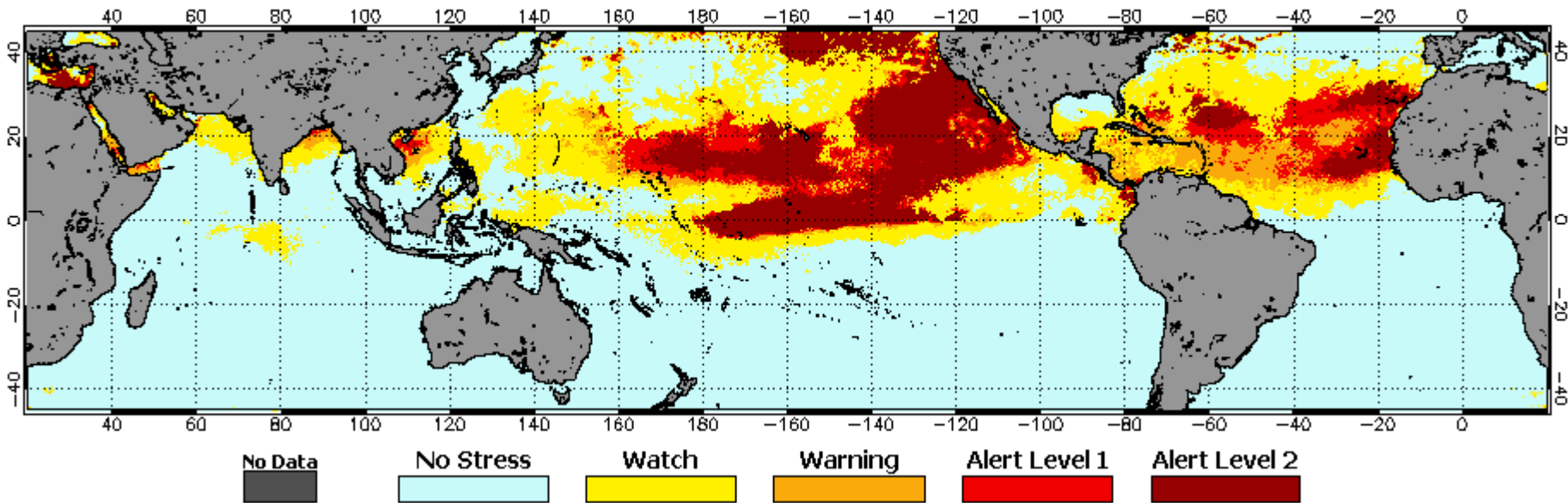


# Satellite Bleaching Thermal Stress Monitoring



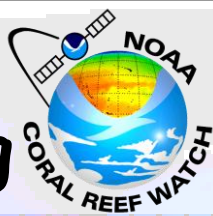
## Bleaching Alert Area

NOAA Coral Reef Watch Daily 5-km Geo-Polar Blended Night-Only Bleaching Alert Area 7d Max 1 Oct 2015



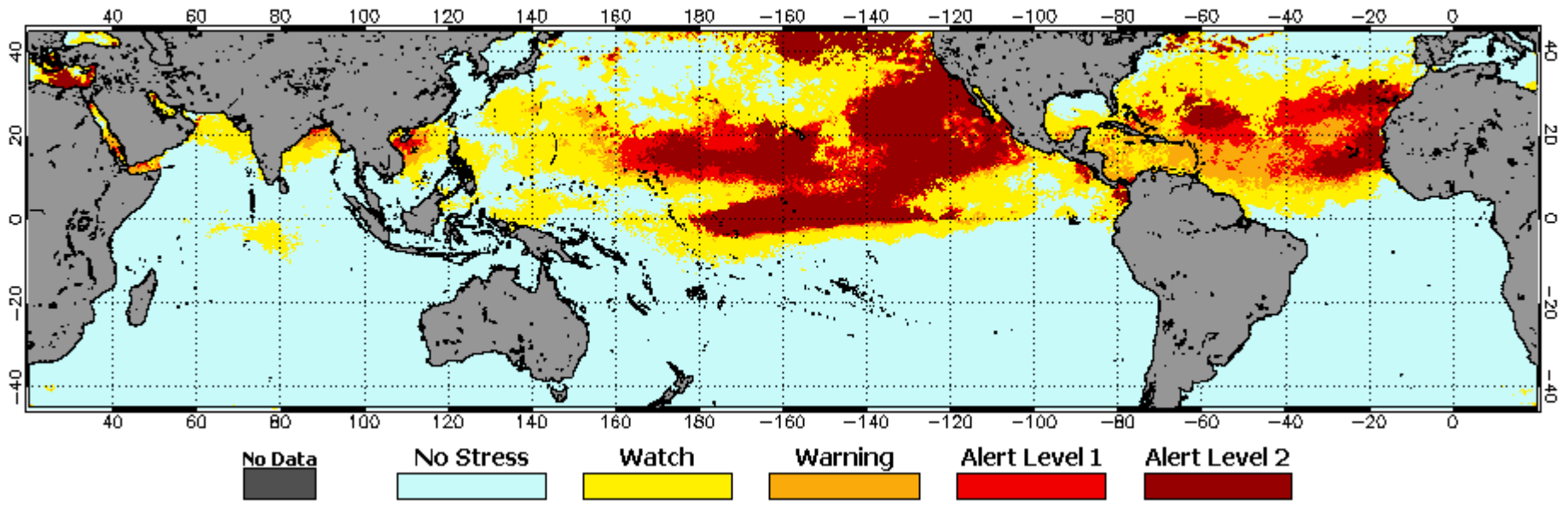
Stress Level	Definition	Potential Bleaching Intensity
No Stress	HotSpot $\leq 0$	No Bleaching
Bleaching Watch	$0 < \text{HotSpot} < 1$	
Bleaching Warning	$1 \leq \text{HotSpot}$ and $0 < \text{DHW} < 4$	Possible Bleaching
Bleaching Alert Level 1	$1 \leq \text{HotSpot}$ and $4 \leq \text{DHW} < 8$	Bleaching Likely
Bleaching Alert Level 2	$1 \leq \text{HotSpot}$ and $8 \leq \text{DHW}$	Mortality Likely

# Satellite Bleaching Thermal Stress Monitoring



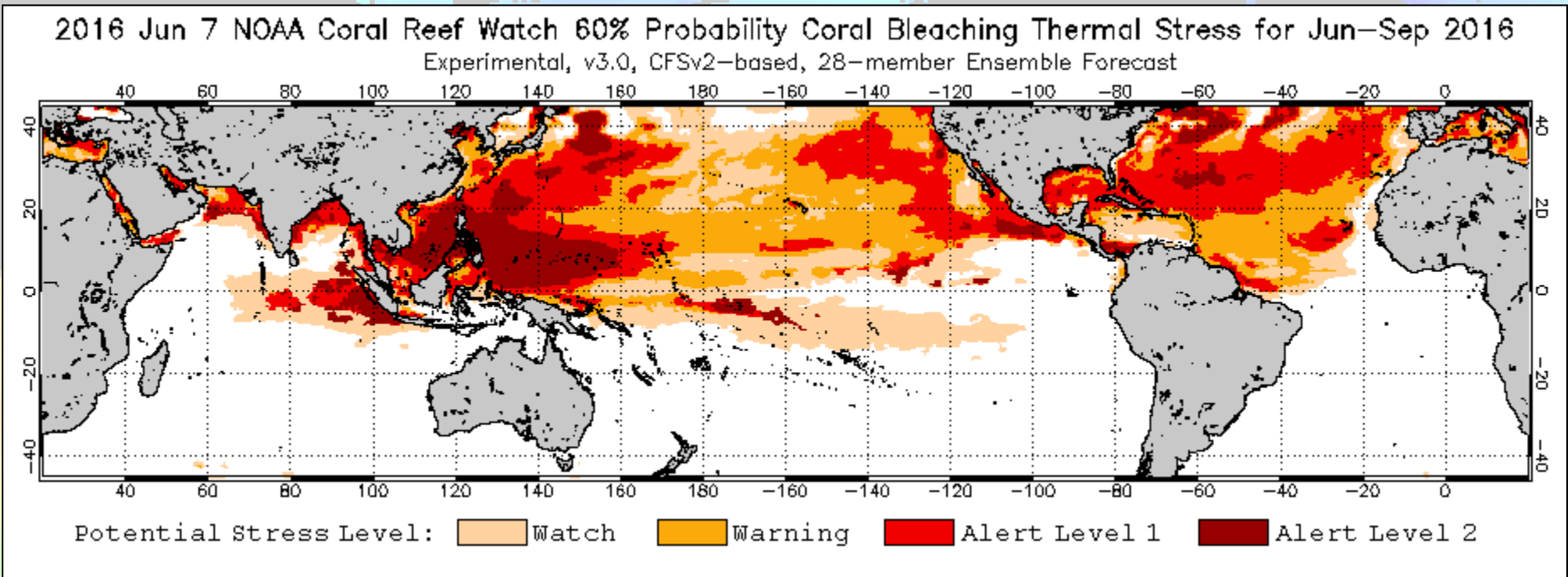
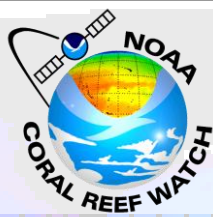
## Bleaching Alert Area

NOAA Coral Reef Watch Daily 5-km Geo-Polar Blended Night-Only Bleaching Alert Area 7d Max 1 Oct 2015



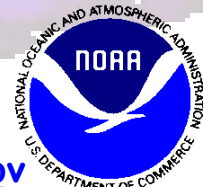
- The only global warning system for coral reef management
- Providing service since 1997:
  - 1997-present: Based on NESDIS 50-km heritage MUT SST
  - 2013-present: Based on NESDIS 5-km Geo-Polar Blended SST

# Model-Based Four-Month Outlook



- The only global near-term outlook for coral reef management
- Providing service since 2008

- Using NCEI 0.25° daily OISST
- Using NESDIS 5-km daily Geo-polar Blended SST



# Ongoing Third Global Coral Bleaching Event

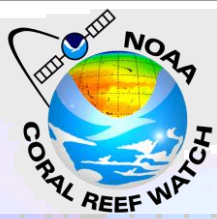
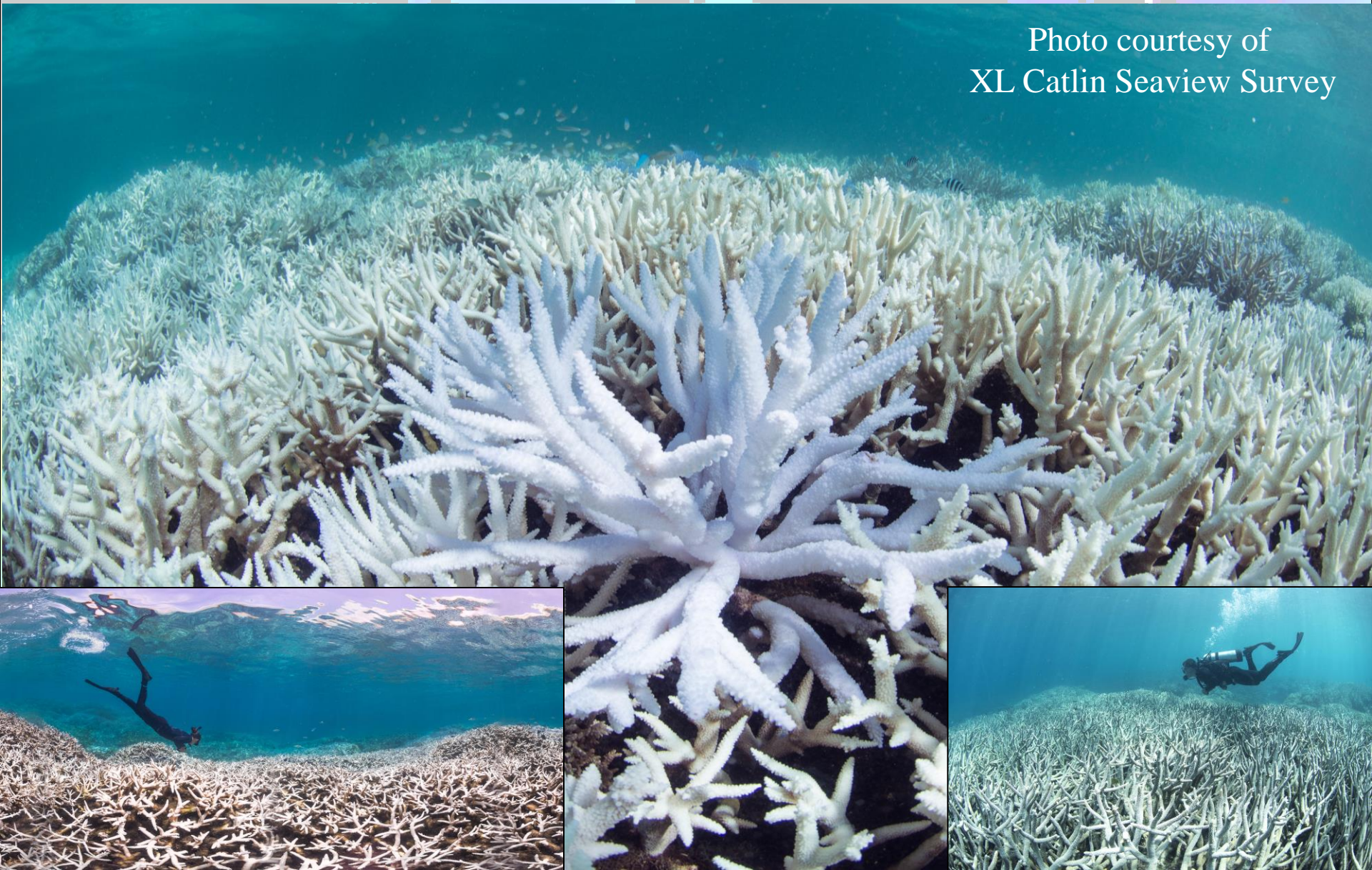
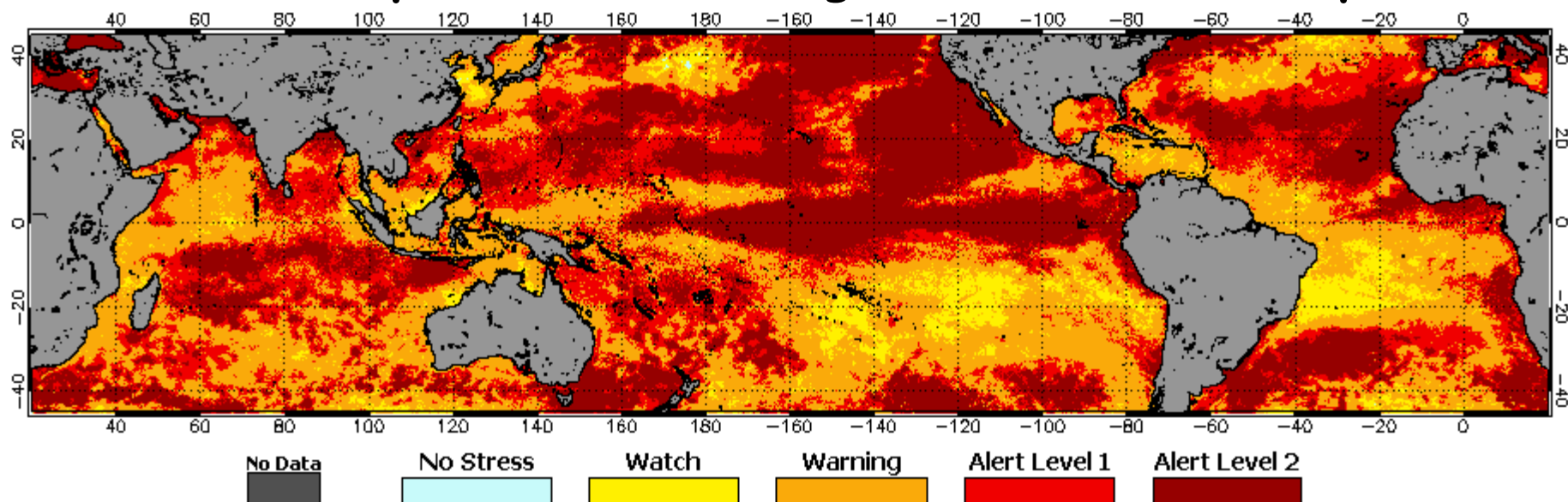


Photo courtesy of  
XL Catlin Seaview Survey



# Ongoing Third Global Coral Bleaching Event

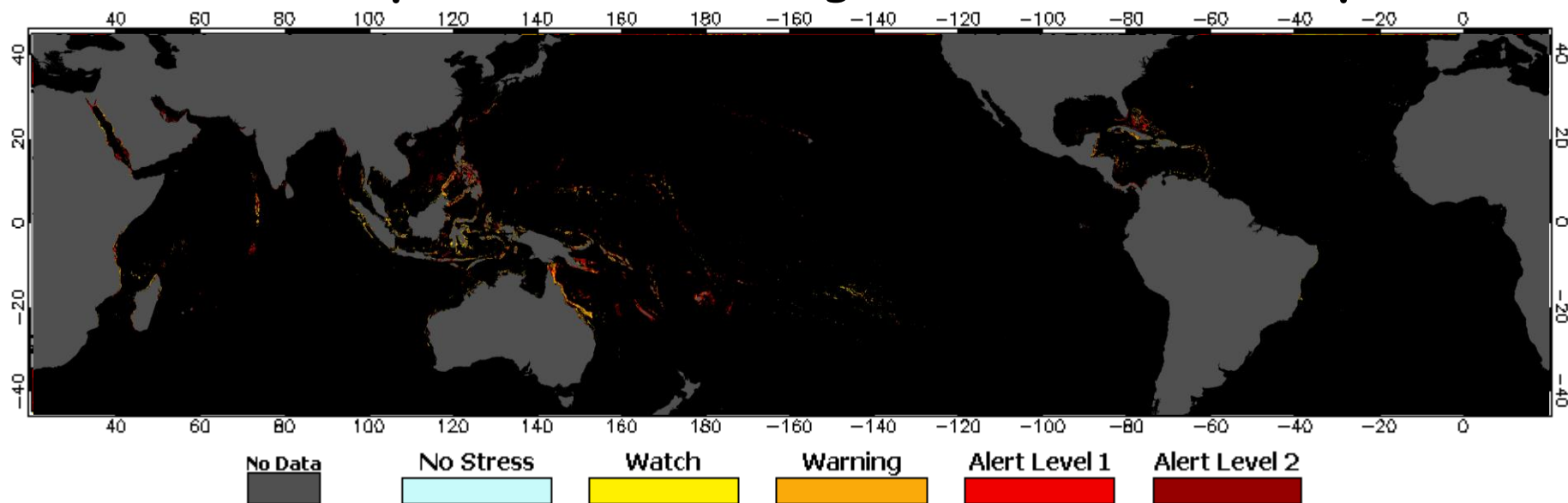
## Maximum Composite of Bleaching Alert Area: 2014-present



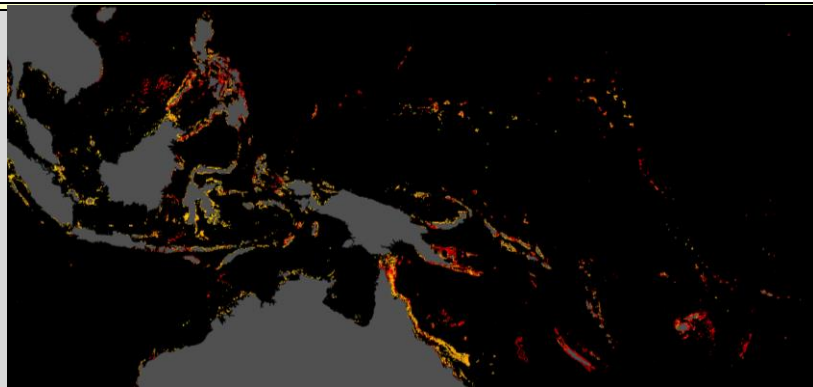
- Started mid-2014
- Spread across all three ocean basins
- Affected most major coral reefs
- Affected all U.S. reefs
- Record-level/worst bleaching on many major reefs (GBR, Kiritimati, Jarvis Island)
- Tied to "Warm Blob", El Niño, and climate-driven increases in ocean temperature

# Ongoing Third Global Coral Bleaching Event

## Maximum Composite of Bleaching Alert Area: 2014-present

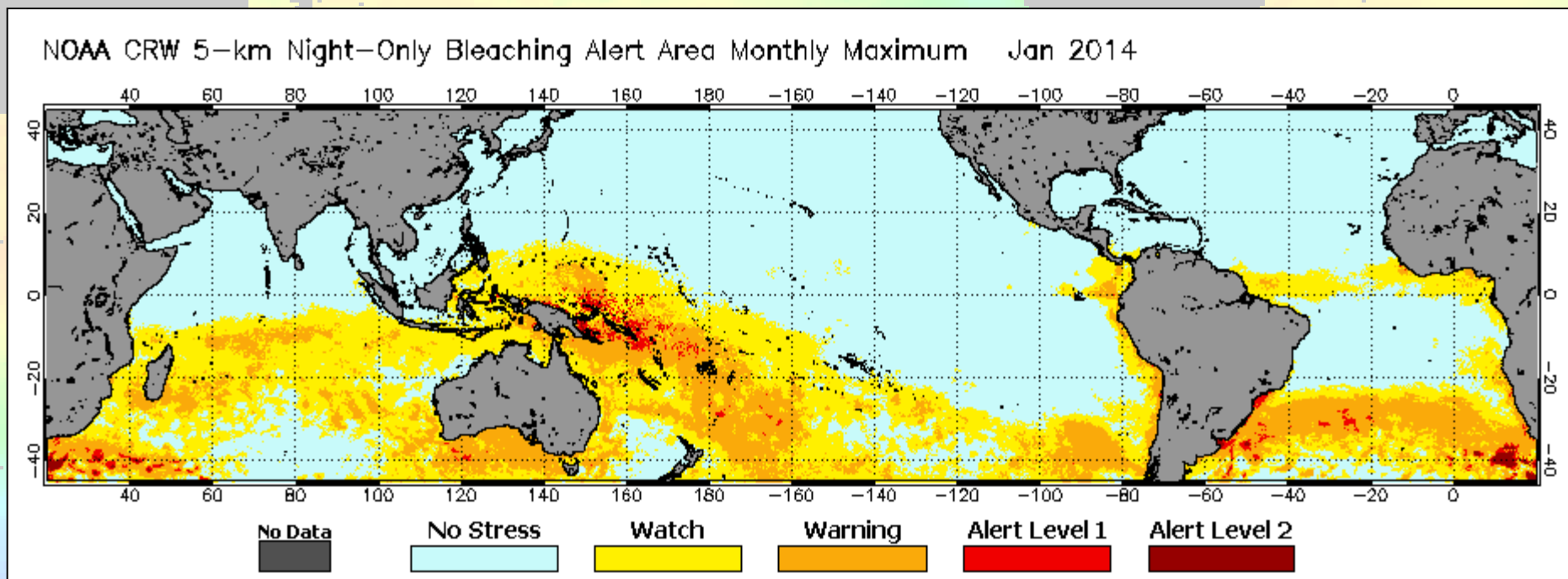


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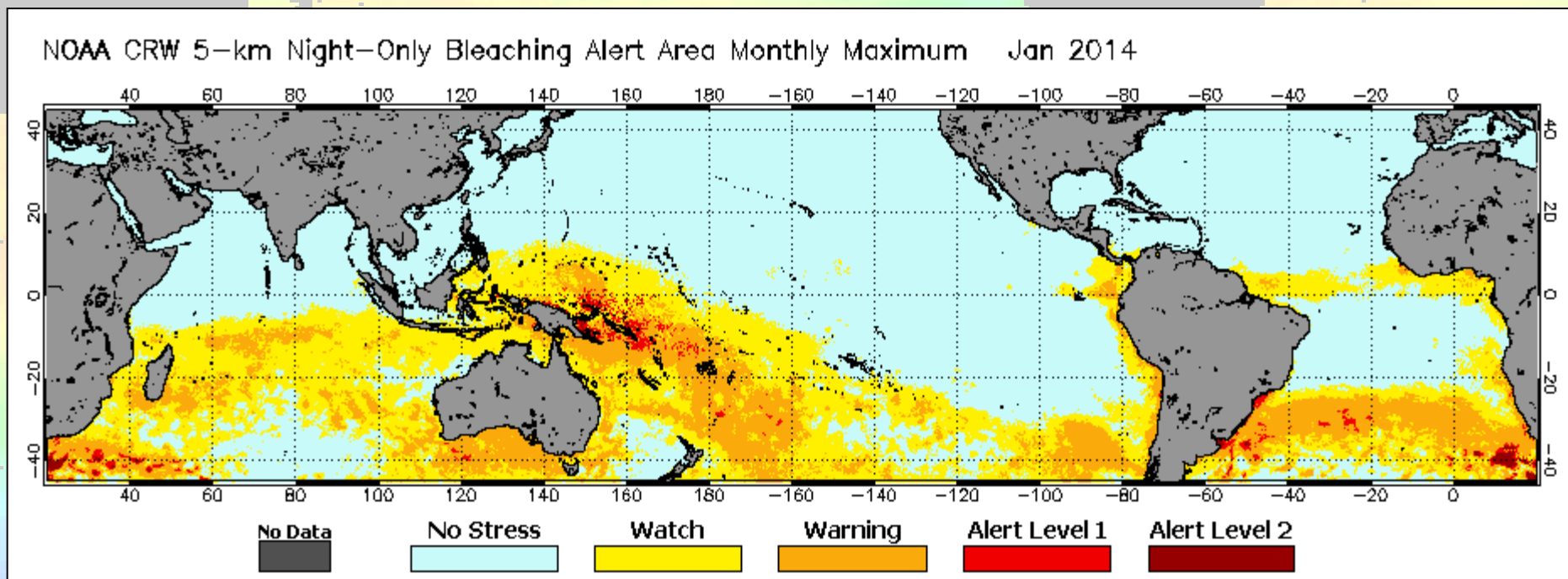
# Ongoing Third Global Coral Bleaching Event

## Animation Maximum Monthly Bleaching Alert Area: 2014-present



# Ongoing Third Global Coral Bleaching Event

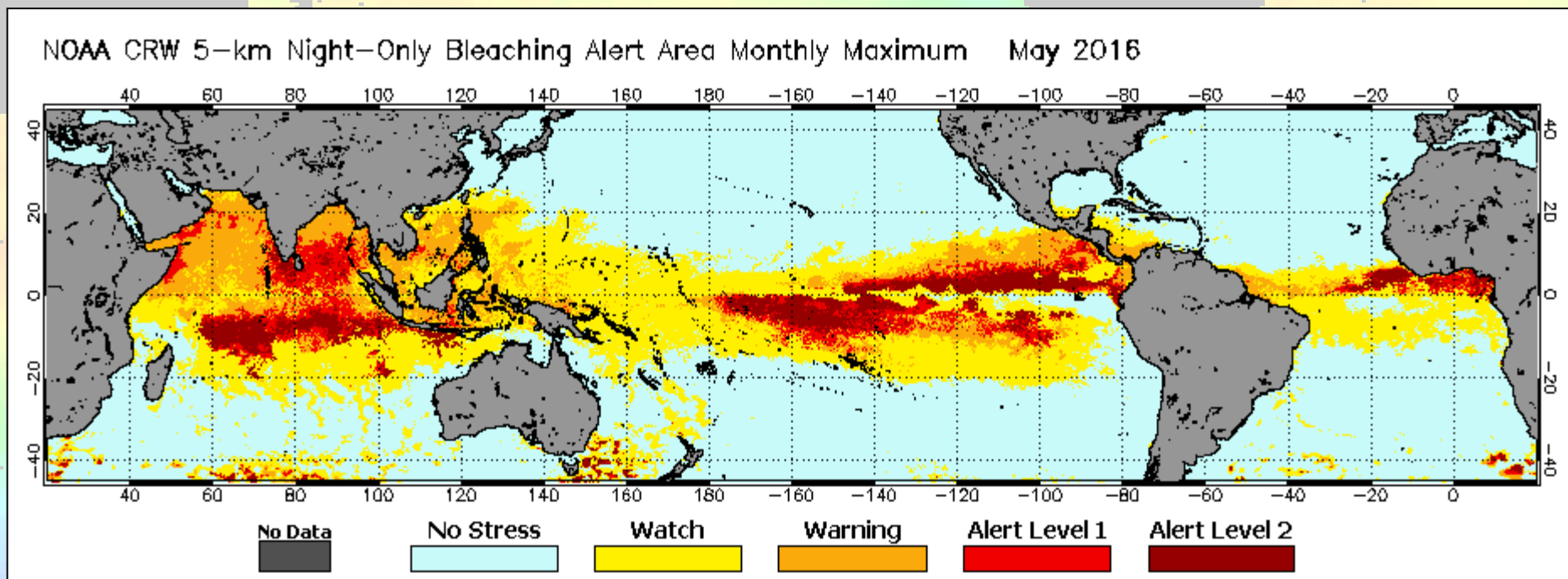
## Animation Maximum Monthly Bleaching Alert Area: 2014-present





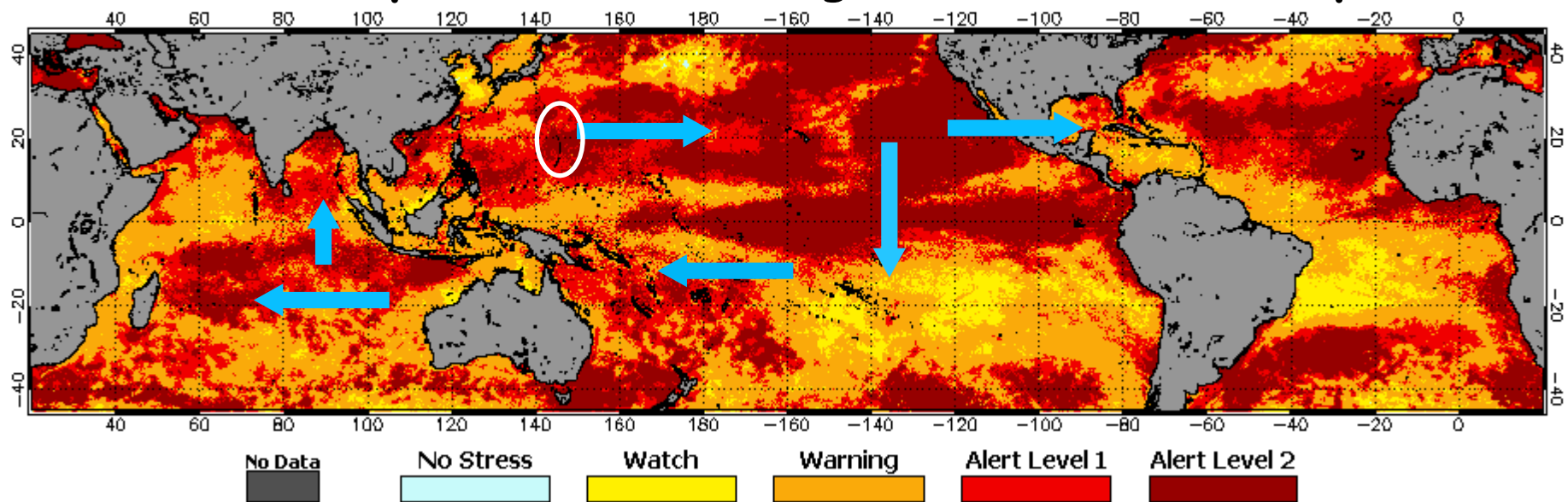
# Ongoing Third Global Coral Bleaching Event

## Animation Maximum Monthly Bleaching Alert Area: 2014-present



# Ongoing Third Global Coral Bleaching Event

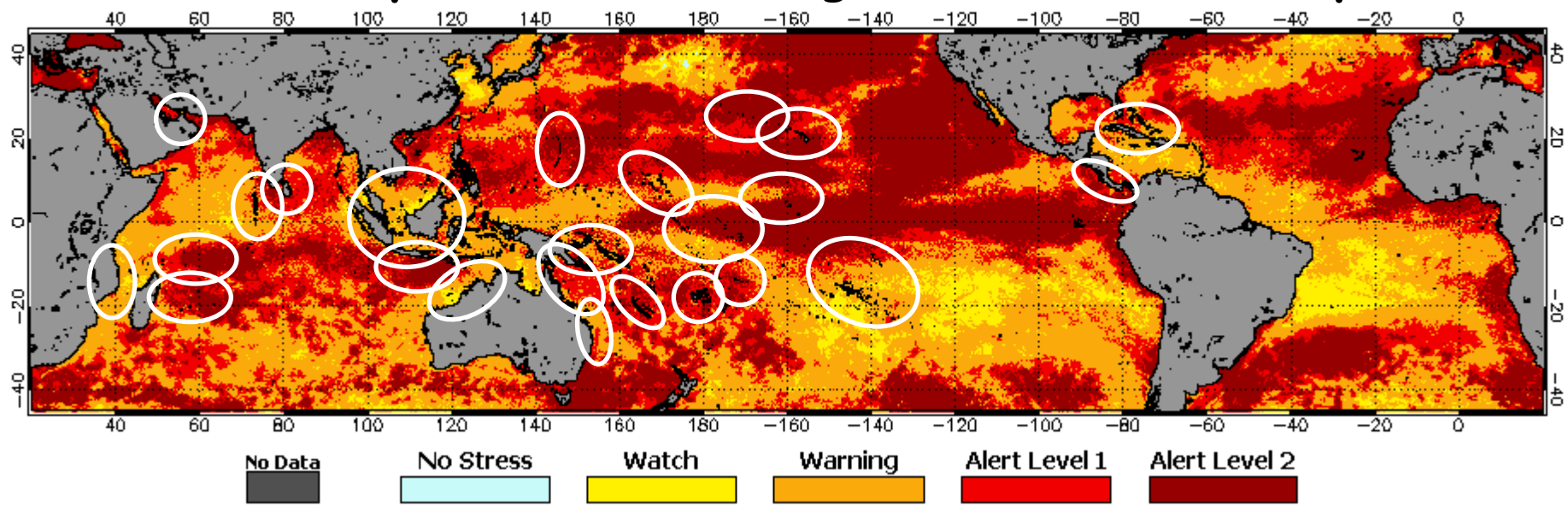
## Maximum Composite of Bleaching Alert Area: 2014-present



- Started mid-2014
- Spread across all three ocean basins
- Affected most major coral reefs
- Affected all U.S. reefs
- Record-level/worst bleaching on many major reefs (GBR, Kiritimati, Jarvis Island)
- Tied to "Warm Blob", El Niño, and climate-driven increases in ocean temperature

# Ongoing Third Global Coral Bleaching Event

## Maximum Composite of Bleaching Alert Area: 2014-present



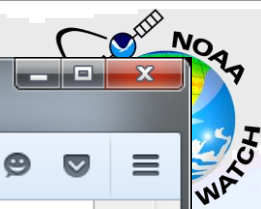
- Started Guam and CNMI in mid-2014
- Spread across all three ocean basins
- The third global bleaching event declared by NOAA in October 2015
- Affected most major coral reefs
- Affected all U.S. reefs
- Record-level/worst bleaching on many major reefs (GBR, Kiritimati, Jarvis Island)
- Tied to "Warm Blob", El Niño, and climate-driven increases in ocean temperature

Healthy - Dec 2014

Dying - Feb 2015

Dead - Aug 2015

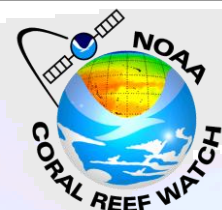
Before, during, and after bleaching at Airport Reef, Tutuila, American Samoa  
(image courtesy of R. Vevers, XL Catlin Seaview Survey)



### Most Recent Bleaching Observations in Press

2016 May 30	<a href="#">Coral death toll climbs on Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 May 27	<a href="#">Update on coral bleaching and mortality in the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 May 13	<a href="#">Update on coral bleaching in the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 May 13	<a href="#">Updated Map of observed bleaching for the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 May 6	<a href="#">Update on coral bleaching in the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 April 20	<a href="#">Press release: Only 7% of Great Barrier Reef has avoided coral bleaching</a>	<a href="#">(Link to the source article)</a>
2016 April 20	<a href="#">Map of reef survey results accompanying Great Barrier Reef press release</a>	<a href="#">(Link to the source article)</a>
2016 April 20	<a href="#">Statement on Great Barrier Reef coral bleaching surveys</a>	<a href="#">(Link to the source article)</a>
2016 April 12	<a href="#">Dead Kiribati reefs mark potential arrival at "dangerous" climate change threshold</a>	<a href="#">(Link to the source article)</a>
2016 April 12	<a href="#">Updated Map of observed bleaching for the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 April 12	<a href="#">Update on coral bleaching in the far northern Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 April 11	<a href="#">ABC-TV News interview with Mark Eakin about Great Barrier Reef bleaching</a>	<a href="#">(Link to the source video)</a>
2016 April 9	<a href="#">Climate-Related Coral Bleaching and Death - A Global Update</a>	<a href="#">(Link to the source article)</a>
2016 April 6	<a href="#">Intense bleaching thermal stress continues devastating reefs of Kiribati</a>	<a href="#">(Link to the source article)</a>
2016 April 5	<a href="#">National Coral Bleaching Taskforce unleashes an armada of experts</a>	<a href="#">(Link to the source article)</a>
2016 April 1	<a href="#">Map of observed bleaching for the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 April 1	<a href="#">Update on coral bleaching in the far northern Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 April 1	<a href="#">El Niño continues devastating reefs worldwide, including the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 March 29	<a href="#">Appeal for underwater photographers and videographers to document bleaching</a>	<a href="#">(Link to the source video)</a>
2016 March 29	<a href="#">Coral Bleaching Taskforce documents most severe bleaching on record</a>	<a href="#">(Link to the source article)</a>
2016 March 21	<a href="#">Scientist witnesses severe coral bleaching at Lizard Island</a>	<a href="#">(Link to the source article)</a>
2016 March 20	<a href="#">Coral mortality rises in remote far northern Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 March 14	<a href="#">Australian National Coral Taskforce puts plan into effect as bleaching intensifies</a>	<a href="#">(Link to the source article)</a>
2016 March 14	<a href="#">Coral Bleaching Intensifies in the Far Northern Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 March 8	<a href="#">Marine Reserve in Reunion Alerts of Coral Bleaching</a>	<a href="#">(Link to the source article)</a>
2016 March 1	<a href="#">Widespread Low Level Coral Bleaching on the Great Barrier Reef</a>	<a href="#">(Link to the source article)</a>
2016 February 25	<a href="#">New Caledonia Mass Bleaching</a>	<a href="#">(Link to the source article)</a>
2016 February 23	<a href="#">El Niño Prolongs Longest Global Coral Bleaching Event</a>	
2015 October 8	<a href="#">NOAA Declares Third Ever Global Coral Bleaching Event</a>	
2015 September 11	<a href="#">Record Ocean Temperatures Causing Coral Bleaching Across Hawaii</a>	
2015 July 6	<a href="#">Coral Bleaching Threat Increasing in Western Atlantic and Pacific Oceans</a>	





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Media Contact:

## Coral bleaching threat increasing in western Atlantic and Pacific oceans

Rising ocean temperatures threaten spread of major heat stress to Hawaiian reefs

**July 6, 2015**

As unusually warm ocean temperatures spread from the north Pacific, equatorial Atlantic oceans, NOAA scientists warn of a new phase of coral bleaching of corals on North Pacific reefs through October, potentially leading to the death of corals over a wide area and a long-term supply of fish and other reef life. While corals can recover from



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## NOAA declares third ever global coral bleaching event

Bleaching intensifies in Hawaii, high ocean temperatures threaten Caribbean corals

**October 8, 2015**

El Niño prolongs longest global coral bleaching event

Climate Oceans & Coasts Fisheries | coral reefs

**February 23, 2016** - Global warming and the current intense El Niño are prolonging the longest global coral die-off on record, according to NOAA scientists, who will present the latest global bleaching update and outlook Friday, Feb. 26 at the 2016 Ocean Sciences Meeting in New Orleans.

Coral Reef Watch 60% Probability Coral Bleaching Thermal Stress for Oct-Jan 2016

Stress Level: Watch Warning Alert Level 1 Alert Level 2

15-January 2016: NOAA's standard 4-month outlook shows a threat of bleaching continuing in the Pacific, Hawaii and Kiribati, and potentially expanding to the Republic of the Marshall Islands. (Credit: NOAA)

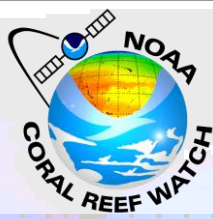
ns there to diminish.

Coral Reef Watch 60% Probability Coral Bleaching Thermal Stress for Feb-May 2016

Stress Level: Watch Warning Alert Level 1 Alert Level 2

May 2016: An extended bleaching outlook showing a high probability of bleaching expected in Kiribati, Galapagos Islands, the Pacific, especially east of the dateline and perhaps in the Indian Ocean, and most coral reef regions in the Indian Ocean. (Credit: NOAA)

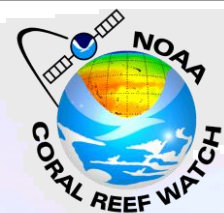




# Future Product Improvements/Requirements

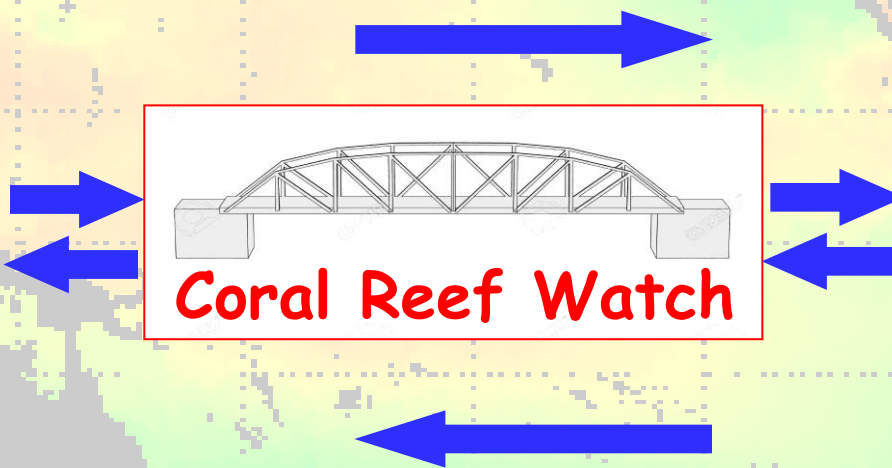
- **SST reprocessing for developing climatology**
  - Current 5-km climatology based on Pathfinder 4-km SST v5.2
  - Transitioning to reprocessed 5-km geo-polar blended SST (back to 2002)
  - Products based on 25-km dOISST produced in parallel for validation/quality assessment
- **Blending microwave, in-situ data into SST analysis**
  - Persistent cloudy areas
- **SST analysis (L4) at finer spatial resolution ( $\leq 1$  km)**
  - Spatial scale of individual reefs: meters to tens of kilometers
  - Great spatial SST gradients in reef areas
- **SST tuned for coastal region**
- **Accurate high-resolution land mask for reef areas**

# End-to-End Service



- Management decision support system
- Workshops (user training and product application)

SST  
data  
providers

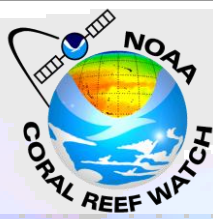


Users  
Coral Reef Managers  
Scientists  
Public

- User product requests/feedback
- In-situ temperature measurements
- Bleaching observations



# Summary



- CRW operates a near-real-time Decision Support System (DSS) for coral reef management
  - U.S. and global coral reef communities
- CRW develops new products to address ever-growing coral reef management needs in a changing climate
  - Applying advances in satellite technology, climate modeling, and coral research
- CRW continues to work with reef managers directly throughout product development, validation and improvement, based on management needs

<http://coralreefwatch.noaa.gov>

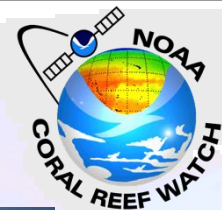
**Coral Reef Watch:** a NOAA/NESDIS program, funded predominantly by the NOAA Coral Reef Conservation Program (CRCP) and supported by Global Science and Technology, Inc.





# NOAA Coral Reef Watch Team

<http://coralreefwatch.noaa.gov>



**Mark Eakin**



**Jacqueline De La Cour (GST)**



**Gang Liu (GST)**



**Kyle Tirak (GST)**



**Erick Geiger (GST)**



**Alan Strong (GST & SR)**



**William Skirving (GST & ReefSense)**

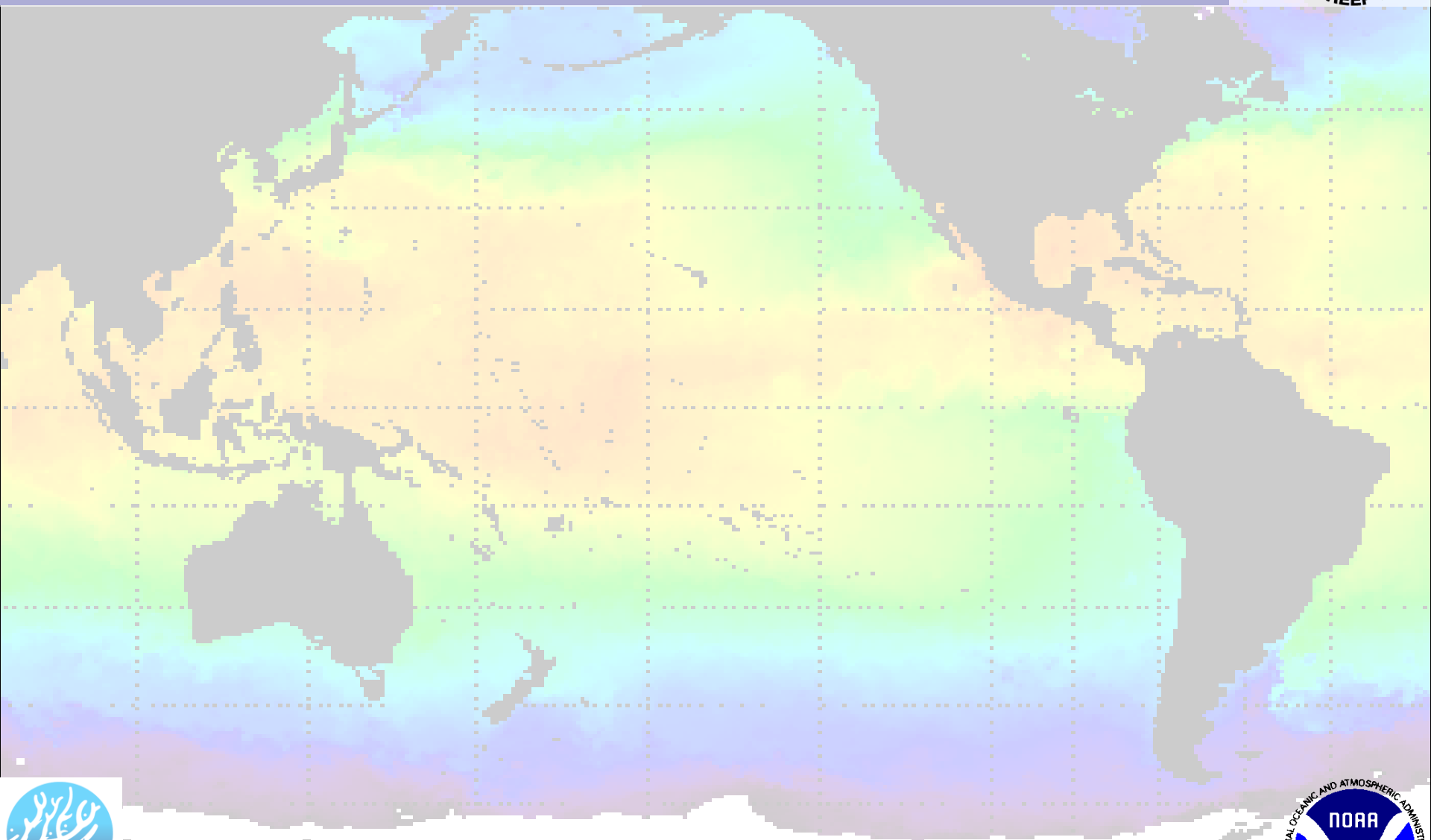


**Scott Heron (GST & ReefSense)**

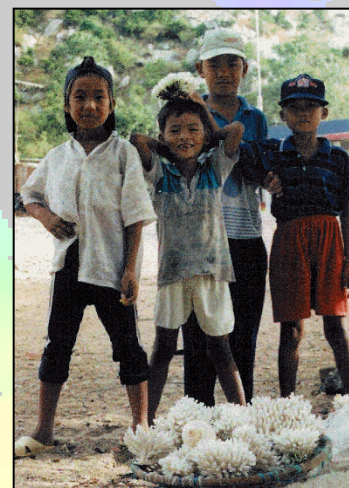


**Andrea Gomez (CCNY & NOAA-CREST)**





# Importance of Coral Reefs



Photos by Anthony R. Picciolo (left) and Heidi Schuttenberg (right)

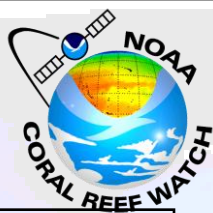
- \* One of the most diverse ecosystems on the earth
- \* One billion people rely on reef fish for food globally

Value of Reefs: \$375 billion (\$100,000-600,000/km<sup>2</sup>)

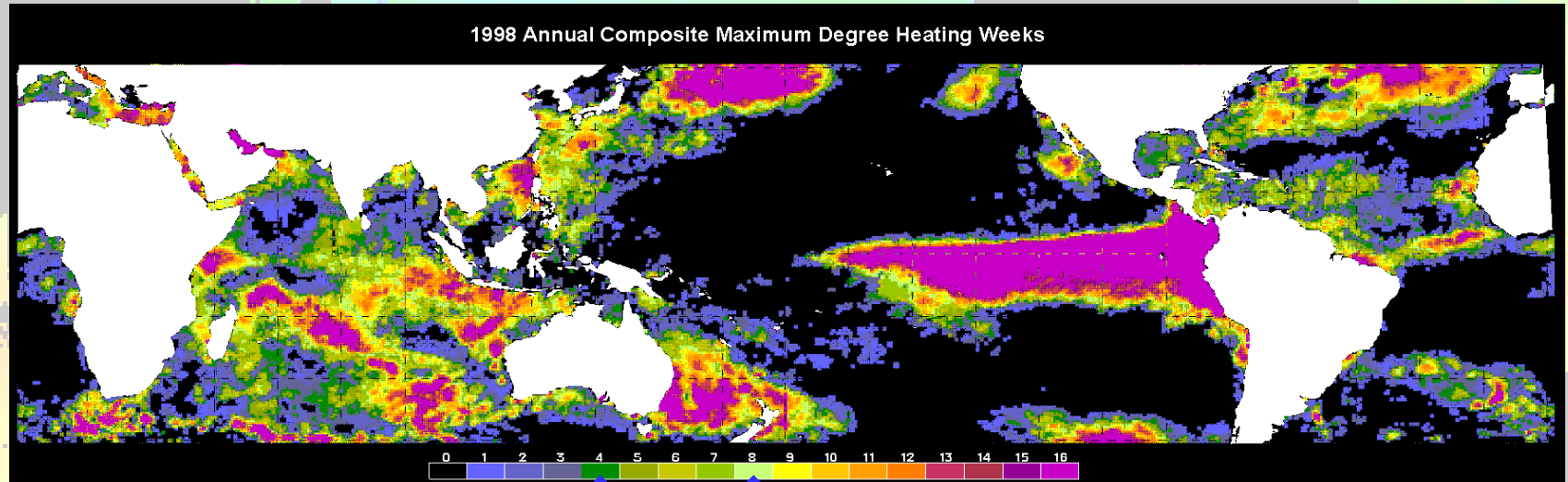
Culture, fisheries, tourism, biomaterials,  
coastal protection (erosion/storm/flooding)

- \$17 billion in U.S. tourism
- 45 million tourist visits to U.S. reefs
- \$246 million in commercial fishing on U.S. reef fish

# Major Bleaching Events



## 1997-1999: Unprecedented Global Mass Bleaching Event (during a strong ENSO event)

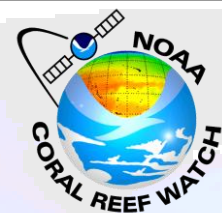


A large El Niño event, immediately switching over to a strong La Niña

Globally the most extensive bleaching event in the modern record for most of the affected regions

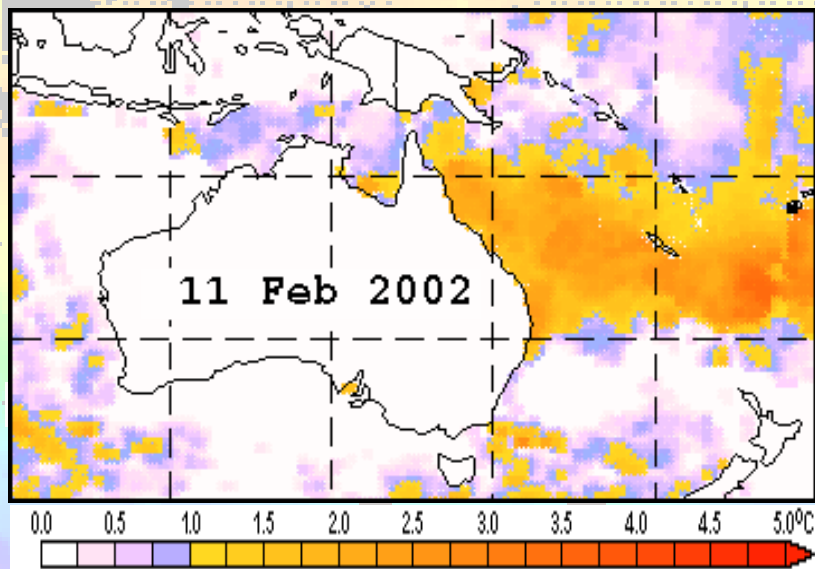
*16% of the world's reefs were destroyed*

# Major Bleaching Events

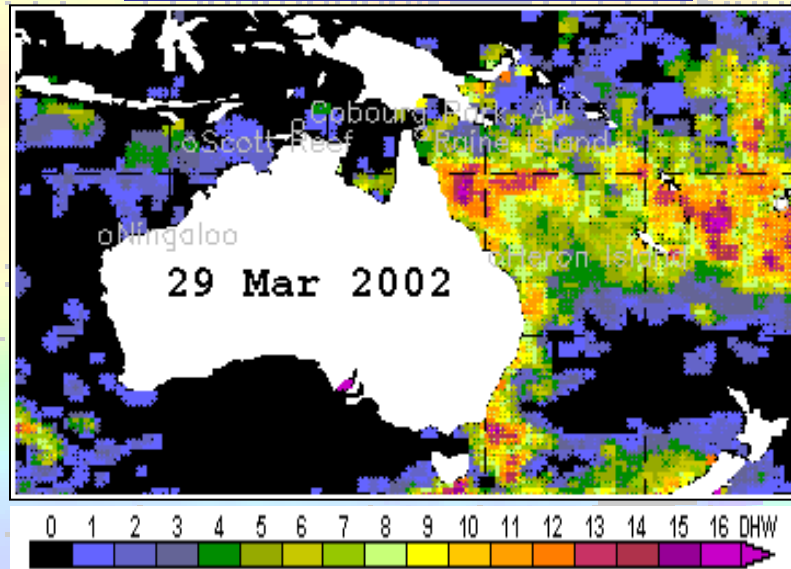


## 2002: Great Barrier Reef, Australia (Unprecedented)

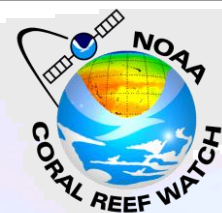
HotSpots (Feb 11, 2002)



DHW (Mar 29, 2002)

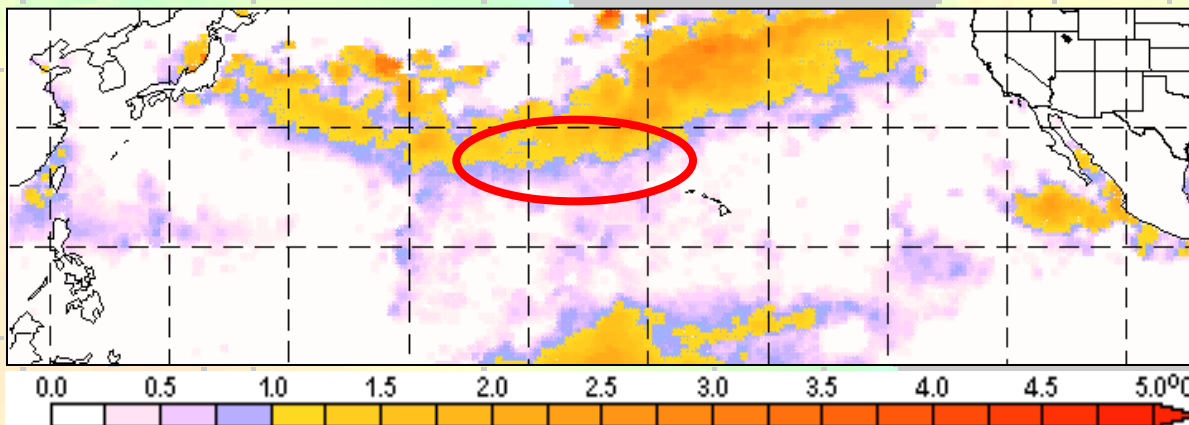


# Major Bleaching Events

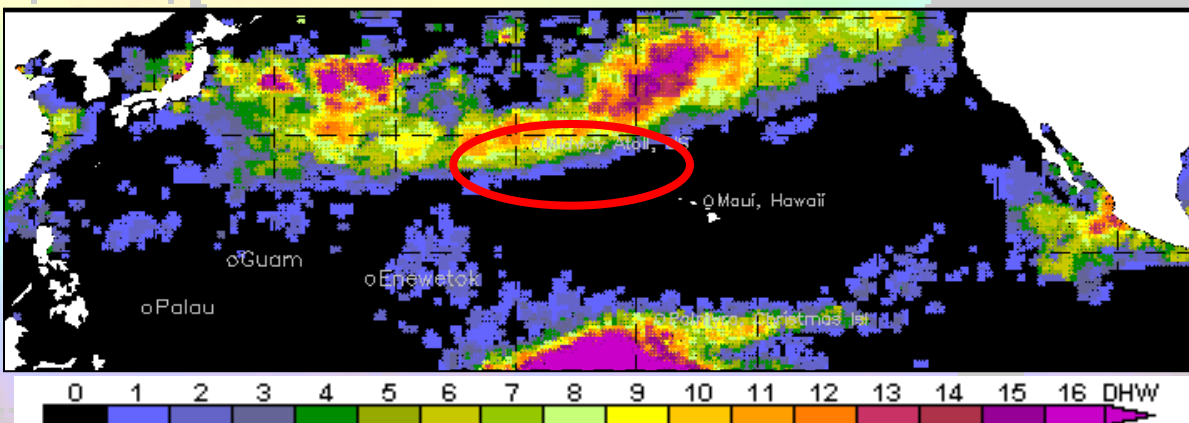


## 2002: Northwestern Hawaiian Islands (Unprecedented)

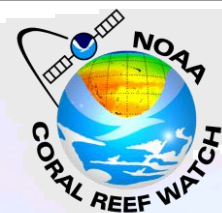
**HotSpots**  
(Sept 2, 2002)



**DHW** (Oct 5, 2002)

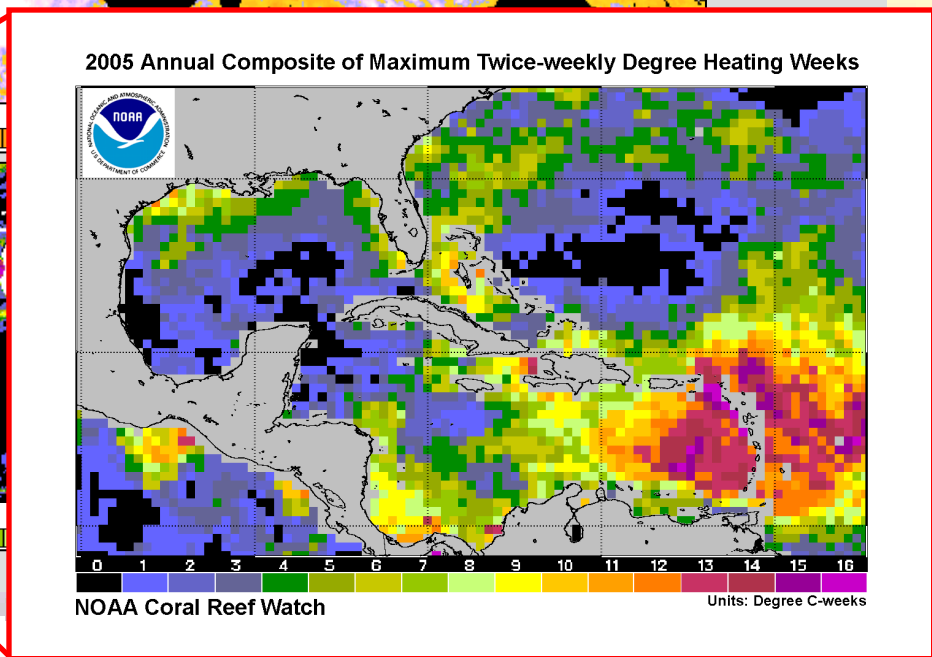
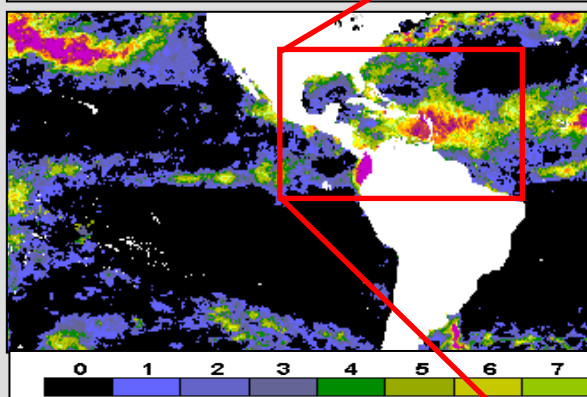
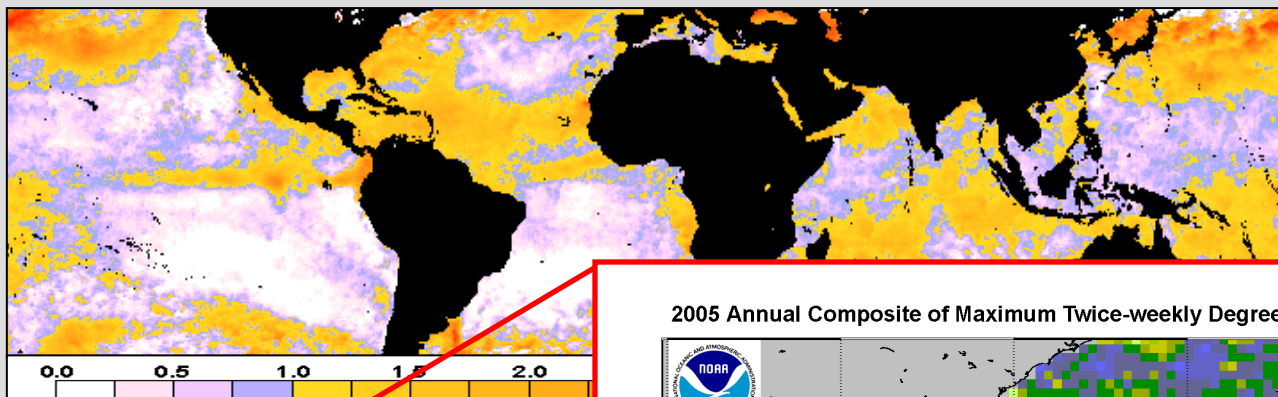


# Major Bleaching Events



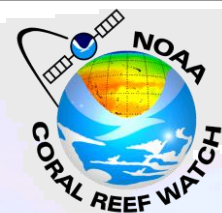
## 2005: Caribbean (unprecedented)

Coral Reef Watch's 2005 Annual Maximum HotSpot and Degree Heating Weeks

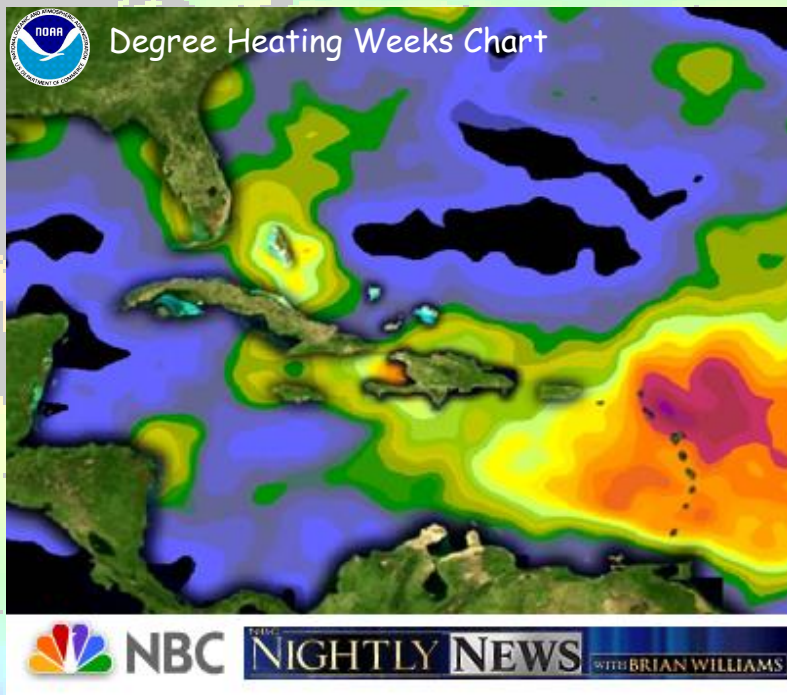




# Major Bleaching Events



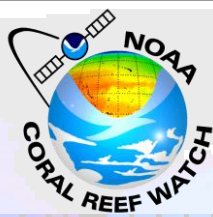
## 2005: Caribbean (unprecedented)



ABC News, CBS News, NBC News, MSNBC, CNN News, USA today, National Geographic, Newsweek, Washington Post ...

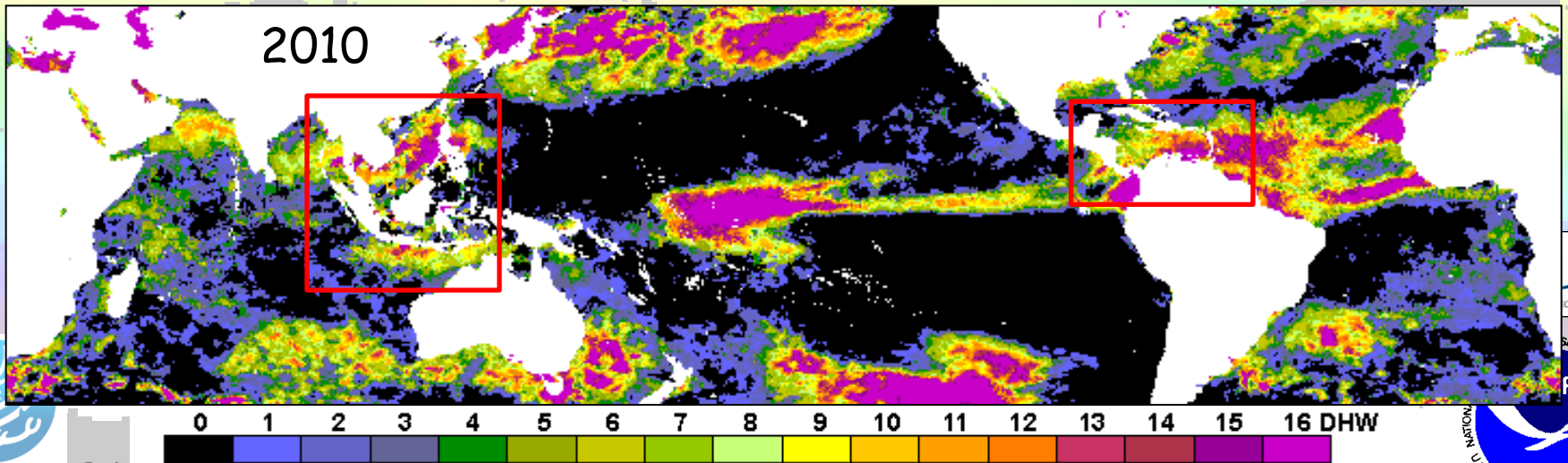
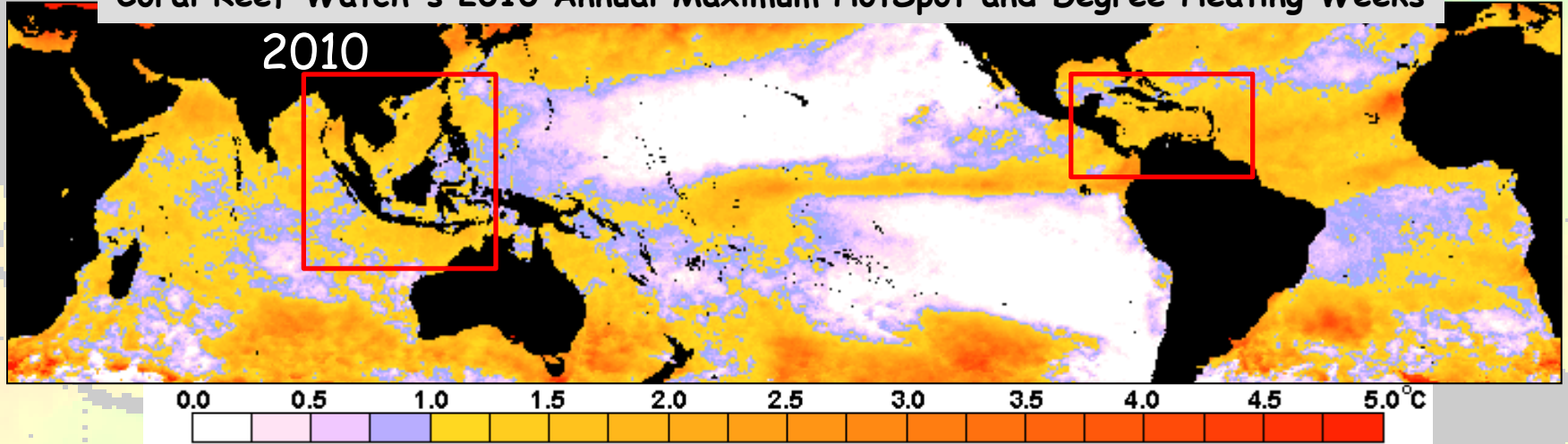


# Major Bleaching Events

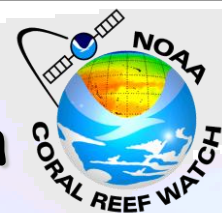


## 2010 Mass Coral Bleaching in Southeast Asia and the Caribbean

Coral Reef Watch's 2010 Annual Maximum HotSpot and Degree Heating Weeks



# Change in Bleaching Thermal Stress in the Caribbean



## 1985-2010 Annual Maximum Degree Heating Weeks

(Based on historical Pathfinder SST and CRW near-real-time SST)

